5A.1 HOW NWS IMPACT STATEMENTS WERE USED TO COMMUNICATE IMMINENT DANGER FROM SEVERE HURRICANES

Barry S. Goldsmith
NOAA/National Weather Service Forecast Office
Tampa Bay Area, Ruskin, FL

1. INTRODUCTION

One of the core missions of the National Oceanographic and Atmospheric Administration's (NOAA) National Weather Service (NWS) is the protection of life and property of American citizens. Over the past few decades, great improvements have been made in forecast and warning services, through increased lead times (Polger, et. al., 1994) and improved tracking precision (Franklin, et. al., 2002) of nature's most hazardous meteorological events. However, warnings of impending disaster are only as effective as the protective action taken by those in harm's way. Despite the noted service improvements, there are still cases when users of NWS warning information are surprised by the outcome.

Surprises in the near term, defined as minutes to a few hours, are likely to be equally a function of whether a message was received as to whether the threat was communicated clearly. For the long term, defined as several hours to days, however, the surprise factor is highly related to how clearly the threat was communicated. The proliferation of modern technology and numerous sources of information make it virtually impossible that persons in harm's way would be unaware that dangerous weather is expected.

Land falling tropical cyclones, particularly major storms rating a Category 3 or higher on the Saffir-Simpson intensity scale (Simpson, 1974), are generally the most life- and property-threatening weather entities in the large scale, affecting tens of thousands of square miles and often millions of people. Such events demand the clearest threat communication, such that people are spurred to action.

A project was born in 1999 to provide real-world impacts from specific wind speed ranges, and storm total rainfall, associated with land falling tropical cyclones, for locations both rural and urban, in semi-tropical climates such as Florida and the Gulf Coast. These impacts would allow users of NWS information to clearly visualize what would actually happen as the cyclone moved through. In 2004 and 2005, real-world impacts were conveyed through NWS local hurricane products, to stunning and awesome results.

* *Corresponding author address: Barry S. Goldsmith, NOAA/National Weather Service, 2525 14th Avenue S.E., Ruskin, FL 33570; e-mail: barry.goldsmith@noaa.gov .*

2. DEVELOPMENT

At the 14th Annual Florida Governor's Hurricane Conference, discussion arose about how to communicate the threat of inland flooding more effectively to those in harm's way. A flood danger scale, similar in scope to the Saffir-Simpson Scale, was proposed. At the same time, some in the Tampa Bay metropolitan region broadcast media were requesting that Hurricane Local Statements, issued by the NWS Weather Forecast Office (WFO) in Ruskin, include real-world impacts for increasing levels of wind threat. In autumn of 1999, staff from the Ruskin office, assisted by members of the local NWS office in Melbourne, FL, created impact wording tailored for residents of Florida and other areas with similar natural and man-made property. Impacts for effects of both wind and flood were developed. Though a true scale was not incorporated, each impact level was associated with a specific range of wind speed or rainfall.

During the following year, these impacts were edited into more concise wording in order to be used as calls-to-action in the same vein as words used for short-fused warnings. By the beginning of 2001, these text segments were incorporated into WFO Ruskin's Advanced Weather Interactive Forecast Processing System's (AWIPS) Watch/Warning/Advisory (WWA) application, where they were first used in locally issued warnings, watches, and statements during Tropical Storm Gabrielle that September. At about the same time, the templates containing the impact wording were shipped to NWS Headquarters in Silver Spring, MD, for final review and national implementation for all offices to use in time for the 2002 season (National Weather Service, 2001).

The WWA application was eventually replaced with an improved text product generator in 2005. However, the impact information included with the tropical cyclone text products in the WWA application was put to the test in at least three of the more recent destructive land falling storms, including Hurricane Charley in 2004 and Hurricanes Katrina and Rita in 2005.

3. WFO TAMPA BAY: HURRICANE CHARLEY

Hurricane Charley began a steady period of intensification on 12 August 2004, as it tracked to the north northwest through the Caribbean Sea south of Cuba. Hurricane Watches were posted by the National Hurricane Center (NHC) for Florida's peninsular Gulf Coast, northward to the mouth of the

Suwannee River, by 1500 UTC. At this point, information provided by the WFO in Ruskin refrained from adding specific impact information during the Watch phase, primarily because Charley was a small storm that still had a reasonable chance of making landfall outside of the WFO's service area of responsibility. This changed six hours later, at 2100 UTC, when Hurricane Warnings were posted for most of Florida's peninsular Gulf Coast. Beginning with the Hurricane Local Statement issued at approximately 2200 UTC on 12 August, and continuing for each issuance until the storm cleared the service area, impacts stressing the potentially ferocious winds were included. With landfall more than 20 h away, such words could be used by the media and decision makers alike to spur people to take protective action well in advance of the onset of wind damage. Figure 1 shows a portion of the wind impact wording.

...VERY DANGEROUS WINDS WILL PRODUCE WIDESPREAD DAMAGE...
...DESTRUCTION OF MOBILE HOMES NEAR THE CENTER OF THE STORM IS POSSIBLE...

...STRUCTURAL DAMAGE...
THE MAJORITY OF MOBILE HOMES WILL BE **SEVERELY DAMAGED** NEAR WHERE THE STORM MAKES LANDFALL. HOUSES OF POOR TO AVERAGE CONSTRUCTION WILL HAVE SIGNIFICANT DAMAGE, INCLUDING PARTIAL WALL COLLAPSE AND ROOFS BEING LIFTED OFF. MANY WILL BE **UNINHABITABLE**. WELL CONSTRUCTED HOUSES WILL INCUR MINOR DAMAGE TO SHINGLES, SIDING, GUTTERS, AS WELL AS BLOWN OUT WINDOWS.

PARTIAL ROOF FAILURE IS EXPECTED AT INDUSTRIAL PARKS...ESPECIALLY TO THOSE BUILDINGS WITH LIGHT WEIGHT STEEL AND ALUMINUM COVERINGS. OLDER LOW RISING APARTMENT ROOFS MAY ALSO BE TORN OFF, AS WELL AS RECEIVING SIDING AND SHINGLE DAMAGE. **AIRBORNE DEBRIS** WILL CAUSE DAMAGE**, INJURY, AND POSSIBLE FATALITIES.**

Figure 1. Wind Impact Wording from Hurricane Local Statement Issued by WFO Tampa Bay, 1201 UTC 13 August 2005. Critical action-inducing words and phrases are **bold**.

The text segment shown above was chosen for expected sustained winds at the high end of Saffir Simpson Scale Category 1 (42.5 m s^{-1} or 95 mi hr^{-1}) with gusts up to 49.2 m s^{-1} (110 mi hr^{-1}, Category 2). Critical key words, such as mobile homes "will be *destroyed*", were added immediately after Charley's core intensified to winds of more than 62.6 m s^{-1} (140 mi hr^{-1}).

Most importantly, the words elicited a response from our first-line customers, including the broadcast media and emergency management community, who were able to effectively amplify the message to the affected population. One of these customers, Chief Forecaster Dick Fletcher of WTSP-TV channel 10 (personal correspondence, 2006), began reading the impact information verbatim during the morning of the 13 August 2004, using a heightened inflection that drove home just how serious this storm would be.

4. WFO NEW ORLEANS: HURRICANE KATRINA

Well-documented Hurricane Katrina rapidly intensified to a Category 5 storm while over the central Gulf of Mexico during the early morning hours of 28 August 2005. Unlike Charley, whose small size and late organization were factors in exacerbating what were, in reality, small track errors (Pasch, et. al., 2004), Katrina became an "extraordinarily large and powerful" (Knabb, et. al., 2005) monster, whose circulation occupied much of the Gulf 36 h prior to landfall. At this point, nearly all the trusted dynamical models showed landfall somewhere along the Mississippi/Louisiana border; in fact, the average error for the entire storm at this time was less than 25 nm! The combination of Katrina's size, intensity, and pinpoint tracking greatly increased the probability of a significant impact on the north central Gulf Coast.

On the morning of 28 August 2005, forecasters at the WFO in Slidell, LA, which serves New Orleans, southeast Louisiana, and southern Mississippi, correctly recognized Katrina to be the worst-case scenario. Noting the 909 mb central pressure and the now-Category 5 intensity, an inland hurricane warning was issued with the highest level of impact. Figure 2 shows the text.

These words, issued nearly 24 h ahead of final landfall near the Mississippi/Louisiana border, triggered a clarion call to the affected population, a call that was soon amplified not only by local broadcast media and emergency management, but also by national media as well. Critical phrases, such as "most of the area will be uninhabitable for weeks" and "water shortages will make human suffering incredible by modern standards" were able to convey a level of danger that may have spurred many more residents to evacuate in an area that had experienced its share of near-misses since Camille in 1969. In fact, preliminary statistics indicated that more than 90 percent of residents in the New Orleans metropolitan area evacuated prior to landfall (U.S. House of Representatives, 2006).

The effectiveness of the WFO-issued impact statements was not lost on Federal Executive and Congressional post-storm assessments. Each report specifically mentioned the statements in the context of proactive decision-making by the federal government in the context of protection of life and property.

URGENT - WEATHER MESSAGE
NATIONAL WEATHER SERVICE NEW ORLEANS
1011 AM CDT SUN AUG 28 2005

...DEVASTATING DAMAGE EXPECTED...

.HURRICANE KATRINA...A MOST POWERFUL HURRICANE WITH **UNPRECEDENTED STRENGTH...RIVALING THE INTENSITY OF HURRICANE CAMILLE OF 1969.**

MOST OF THE AREA WILL BE UNINHABITABLE FOR WEEKS, PERHAPS LONGER. AT LEAST ONE HALF OF WELL CONSTRUCTED HOMES WILL HAVE ROOF AND WALL FAILURE. ALL GABLED ROOFS WILL FAIL...LEAVING THOSE HOMES SEVERELY DAMAGED OR DESTROYED.

THE MAJORITY OF INDUSTRIAL BUILDINGS WILL BECOME NON FUNCTIONAL. PARTIAL TO COMPLETE WALL AND ROOF FAILURE IS EXPECTED. ALL WOOD FRAMED LOW RISING APARTMENT BUILDINGS WILL BE DESTROYED. CONCRETE BLOCK LOW RISE APARTMENTS WILL SUSTAIN MAJOR DAMAGE...INCLUDING SOME WALL AND ROOF FAILURE.

HIGH RISE OFFICE AND APARTMENT BUILDINGS WILL SWAY DANGEROUSLY, A FEW TO THE POINT OF TOTAL COLLAPSE. ALL WINDOWS WILL BLOW OUT.

AIRBORNE DEBRIS WILL BE WIDESPREAD, AND MAY INCLUDE HEAVY ITEMS SUCH AS HOUSEHOLD APPLIANCES AND EVEN LIGHT VEHICLES. SPORT UTILITY VEHICLES AND LIGHT TRUCKS WILL BE MOVED. THE BLOWN DEBRIS WILL CREATE ADDITIONAL DESTRUCTION. **PERSONS, PETS, AND LIVESTOCK EXPOSED TO THE WINDS WILL FACE CERTAIN DEATH IF STRUCK.**

POWER OUTAGES WILL LAST FOR WEEKS, AS MOST POWER POLES WILL BE DOWN AND TRANSFORMERS DESTROYED. **WATER SHORTAGES WILL MAKE HUMAN SUFFERING INCREDIBLE BY MODERN STANDARDS.**

Figure 2. Wind impact wording from Inland Hurricane Warning Issued by WFO New Orleans, 1511 UTC 28 August 2005. Critical, action-inducing phrases are **bold**.

In fact, the impact development efforts were noted, positively, by the Executive Report (The White House, 2006):

> " Members of the National Weather Service knew that the time would come to issue warnings, and they developed them ahead of time, evaluating data and basing the warning language on various scenarios, so that when certain criteria were met (as with Hurricane Katrina), they did not have to waste time creating statements—they could issue them immediately."

5. FUTURE PLANS

The continuing transformation to a graphics oriented society has been welcomed by NWS with the creation of the digital services concept (Austin, et. al., 2005). Surveys (Claus-Fornell International, et. al., 2003) have shown an increasing demand for graphical weather information, particularly on the internet. NWS offices in hurricane-prone locations have been experimenting with various methods of highlighting tropical cyclone hazards for the past several years, and plans are in place to create an NWS-wide standard within a few years. Probabilistic data will be applied in the future, in order to solidify the scientific basis of the graphics to further improve threat communication.

The WFOs in Florida each have created versions of graphical tropical cyclone hazards for their respective internet web pages. Figure 3 is an example of what a color-coded graphic might have looked like for the expected wind impacts from Hurricane Charley; Figure 4 is a user-selected text "pop-up" window for the extreme case. The text in these windows is only slightly abbreviated from words used in the actual message. These graphics become active when a tropical cyclone threatens Florida's peninsular Gulf Coast and can be found at http://www.srh.noaa.gov/tbw/html/tbw/ghls.htm

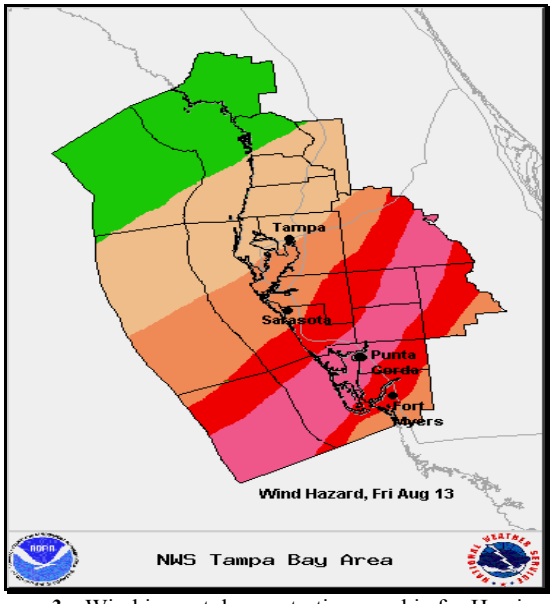

Figure 3. Wind impact demonstration graphic for Hurricane Charley's approach. Green=none; beige=low, orange=moderate, red=high, and magenta=extreme.

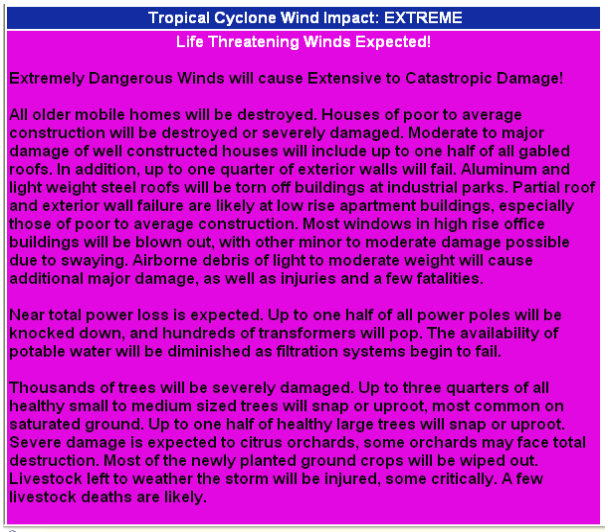

Figure 4. Clickable text window associated with category 3 sustained winds (magenta/purple), as shown in Figure 3.

Most recently, real-world impacts for storm surge along a typical low-lying coastline were added during the 2005 season to be used in both graphical and textual products. Surge flooding examples from Hurricanes Katrina and Ivan, in 2004, were used as guidelines.

6. SUMMARY AND CONCLUSIONS

Effective communication of meteorological hazards to the general population has always been one of the most challenging aspects of weather forecasting. Each year, there are a few significant events that are considered a "surprise" to many people, despite the fact that ample warnings were issued. During post-mortems, the question of "How can this be?" arises, and often the answer is not in the warnings themselves, but in the clear message they fail to send. Studies referenced by Morrow (2005) underscore this reality.

For many, the questions are as simple as "Will we die or get hurt?" or "Will our property be destroyed?". The project born in 1999 to create real-world text information for increasing levels of wind speed and rainfall, and most recently storm surge, is a step in the right direction toward answering these questions.

Hurricanes Charley in 2004, and Katrina in 2005, provided an opportunity to use these real-world impacts for life-threatening situations for residents and visitors of the Florida Peninsula and southeast Louisiana/southern Mississippi, respectively. While difficult to quantify the effectiveness of key terminology such as "suffering will be incredible by modern standards" in terms of motivating communities to act, there is consensus that these phrases, used in official federal warning messages, conveyed an unusual sense of urgency for broadcast media and emergency managers, who quickly relayed the information to those in harm's way.

Most importantly, however, are the lives that may well have been saved. People, particularly in southeast Louisiana and southern Mississippi that normally insist on riding out such storms, decided to evacuate this time, even at the last minute. The careful use of words that resonated with the average citizen may well have made a difference. For that, we can all be thankful.

7. ACKNOWLEDGEMENTS

The author would like to thank Mr. Walt Zaleski, Warning Coordination Meteorologist, NWS Southern Region, Mr. Charles Paxton, Science and Operations Officer, NWS WFO Tampa Bay, Florida, Mr. Ira Brenner, Meteorologist-in-Charge (ret.), WFO Tampa Bay, Florida, and Mr. Shawn Bennett, Meteorologist-in-Charge, WFO Tampa Bay, Florida, for supporting this effort. The author would also like to thank Mr. Glenn Austin, NWS Office of Climate, Water, and Weather Services, for offering the original concept back in 1999.

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